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shortening the time of exposure gave encouraging results. A shortening of the time of exposure and the simplification of the apparatus employed is very desirable in the practical application of this wonderful discovery. The prospects are that both will soon be reached. It should be mentioned in this connection that a Whimshurst or a Holtz machine can very well be employed in place of the somewhat complicated apparatus employed so far. These machines should be used to charge a small Leyden jar and discharge it between small spheres which are at a suitable distance from each other. The tinfoil coatings of the vacuum tube should then be connected suitably to the coatings of the jar. This arrangement is much simpler than the one usually employed and will in all probability give just as good results—perhaps even better, because a disruptive character of the discharges seems to improve the results. This method, however, is offered as a suggestion only, since the writer could not procure a statical machine in time to convince himself of the actual value of the suggested arrangement. The practical applicability of this method of photography to surgery seems certain.

M. I. PUPIN.

COLUMBIA COLLEGE, February 8, 1896.

EXPERIMENTS ON THE X-RAYS.

EXPERIMENTS with Röntgen's newly detected X-rays have been carried on during the past few days in the Dartmouth physical laboratory by Prof. C. F. Emerson and the writer, and some of the preliminary results already obtained may be worth recording.

Of four Crookes tubes first tried, but one emitted rays which (with the exposure given) made a visible impression upon a photographic plate protected from the ordinary luminous rays. This tube is 4.7 cm. in diameter and is cylindrical for a length of 16 cm., then tapering to a point. The platinum electrodes are on opposite sides of

the cylindrical surface and are about 5 cm. apart. A phosphorescent plate is interposed obliquely between the electrodes. In action the phosphorescent surface is bombarded by the discharge from the negative pole. We have thus far usually excited the tube by a current from an efficient induction coil, but a Holtz machine has served about equally well.

The first successful experiment gave, after 12 minutes of exposure, a picture of a knife and scissors hung on the side (1 cm. thick) of a whitewood box, within which the photographic plate had been placed.

Subsequently, the Crookes tube was supported horizontally, and the plate-holder could then be laid upon the table and any object interposed that was desired. No camera was employed, and the slide of the plate holder was not drawn, so that no exposure to the ordinary luminous rays could occur.

A coin and key concealed between two boards of total thickness, 24 mm., were shown after an exposure of 11 minutes, the tube being 15 cm. above the plate. The power of transmitting the X-rays has been tested for a number of substances. Silver and gold seem to be the most opaque of the metals yet tried, although aluminium transmits poorly. Glass is more opaque than brass, and less so than hard rubber. Cork transmits better than any other substance examined. (See Plate 4, Fig. 1.)

An attempt to refract the rays by a carbon disulphide prism was unsuccessful, and they seemed to pass through a pair of crossed tourmalines without difficulty. No effect except that of the usual metallic obstruction was noted when the wire conveying the primary current was passed over the plate, or when the alternate current of the house circuit was sent through a loop of insulated wire resting on the plate holder.

With the tube 9 cm. above the plate an exposure of 15 minutes clearly brought out

the bones of a hand laid upon the plate holder, and subsequent plates have revealed the bones of the hand and arm with startling distinctness. (See Plate 3, Fig. 2.)

It was possible yesterday to test the method upon a broken arm. After an exposure of 20 minutes the plate on development showed the fracture in the ulna very distinctly. Comment upon the numerous applications of the new method in the sciences and arts would be superfluous.

EDWIN B. FROST.

HANOVER, N. H., February 4, 1896.

EXPERIMENTS ON THE RÖNTGEN X-RAYS.

DURING the past week experiments have been in progress in the physical laboratory of the University of Pennsylvania on the Röntgen phenomena. The apparatus has been gradually simplified till now only a single induction coil about 12 inches long and $4\frac{1}{2}$ inches in diameter is used. The resistance of the primary is about 0.3 of an ohm, and that of the secondary about 3,200 ohms. The current for the primary is supplied by eight or ten storage cells connected two in multiple arc. The Crookes tube is a pear-shaped one about 10 inches long and $4\frac{1}{2}$ inches in diameter at the larger end. The exposure has been inconveniently long, an hour or more giving the best results.

Impressions of several surgical cases, including deformed fingers, fractures, etc., have been successfully produced. The results seem to be best where the tube is about 5 inches from the sensitive plate, with its longer axis vertical and the cathode at the top. A card with a broad line of white lead paint upon it was used, showing the card transparent and the paint opaque.

Special experiments made by Dr. H. C. Richards indicate that amethyst, quartz, calc spar, mica and tourmaline are quite opaque. In one of the experiments a $\frac{3}{8}$ -inch aperture in a copper screen was placed

$2\frac{1}{2}$ inches below the tube. The sensitive was $3\frac{1}{2}$ inches below the aperture. The result showed that the rays in passing through the opening were considerably diffused. Experiments have been arranged to examine the possible deviation of the rays in passing through a wooden prism. The results as yet are not conclusive. The pictures accompanying this article (see Plate 4) are some of a number taken on February 5th and 6th. One shows a thick leather pocket purse containing a couple of coins. Upon the same plate were placed a slip of thin glass and a bit of aluminium tube. As is seen, the glass and aluminium seem equally opaque. Another of the cuts shows the outlines of a pocket pincease taken by Dr. R. R. Tatnall. Every pin shows clearly in its place. Some flowers painted upon one of the surfaces are quite visible in the negative.

In our experiments the sensitive plates have been enclosed light-tight in an ordinary plate holder and placed horizontally upon the table beneath the tube. Upon the slide of the plate holder were placed the articles to be tested.

The wide field for the development and the application of the new science will become apparent to everyone. As has already been suggested, it may prove to be an efficient mode of examination for the surgeon. It may also be used to judge the genuine from the false as in the detection of a spurious diamond or other gem from the real.

As the X-rays are not light rays, but probably are some form of radiant energy, the writer has suggested the term *radiography* instead of photography for the new process.

The comments of several scientists that the form of wave motion transmitting the energy concerned in the Röntgen phenomena is longitudinal and not transverse, have especial interest. It is shown in a recent article by G. Jaumann, in Wiede-